NATIONAL HIGH MAGNETIC FIELD LABORATORY 1800 East Paul Dirac Drive • Tallahassee, Florida 32310 • 850-644-0311 VOLUME 10 • NO. 3 • 2003
LAB SPOTLIGHTS REPRINTED FROM NHMFL REPORTS http://www.magnet.fsu.edu

The NHMFL Ultra-High B/T Facility: *A Study of Transport in Highly Polarized Fermi Fluids*

Neil Sullivan, NHMFL Co-Principal Investigator, Dean of the UF College of Liberal Arts and Sciences, and former chair of the UF Department of Physics

The National High Magnetic Field Laboratory operates a specialized facility at the University of Florida to meet the needs of users who require both high magnetic fields and ultra-low temperatures simultaneously for their experimental investigations. This facility, known as the NHMFL High B/T facility, is designed with a high refrigeration capability to permit studies over a wide range of applications for extended periods of time. A 5-mole $PrNi_5$ nuclear demagnetization refrigerator provides the high cooling power, and following a demagnetization from 8 T beginning at 10 mK, this refrigerator can maintain temperatures below 1 mK for over 100 days, provided the heat leaks are kept below 8 nW.

An ultra-quiet environment is provided to reduce heating due to external electromagnetic fields, and this enables experimenters to carry out highly sensitive measurements on samples held at sub-millikelvin temperatures. An advanced vibration isolation support structure reduces the mechanical vibrations that can lead to eddy current heating in the metallic components that are located in the magnetic field. The entire experimental structure is housed inside a ***tempest*** quality electromagnetic screened room to reduce heating from radio-frequency sources. The current magnetic field capability for the experimental region is limited to 15.5 T, and experiments can be carried out at temperatures down to 0.4 mK (a limit resulting from the nuclear ordering of the $PrNi_5$).

A number of new research studies have been made possible with the use of this facility. One of the projects recently completed has been the investigation of transport in highly polarized Fermi fluids, an NHMFL In-House Research Program-funded research project lead by Don Candela of the University of Massachusetts. A distinct anisotropy is predicted for the transport of magnetization and for the spin diffusion for highly polarized Fermi liquids.[1] This is due to the difference in phase space scattering for the spin-up and spin-down Fermi spheres. For a spin polarization, P, the diffusion constant for motion in a plane perpendicular to the applied magnetic filed is given by

$$D_{\perp} = \frac{D_0}{1+[T_a(P)/T]^2}$$

where $D_0 = \frac{1}{3} v_F^2 \tau_F$, v_F is the Fermi velocity and τ_F is the mean time between scattering

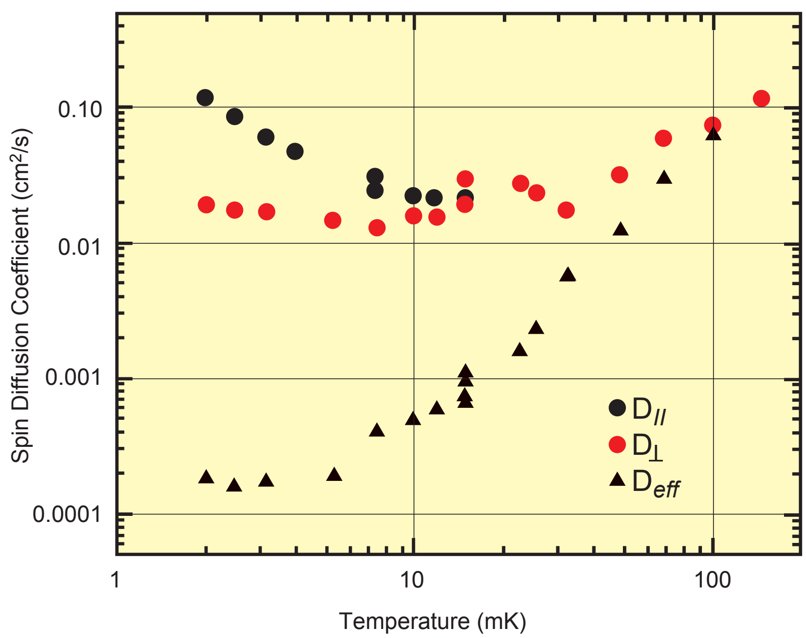

Figure 1. Results of NMR measurements of the nuclear spin diffusion of ^3He dissolved in ^4He for a ^3He concentration of 3.8%.

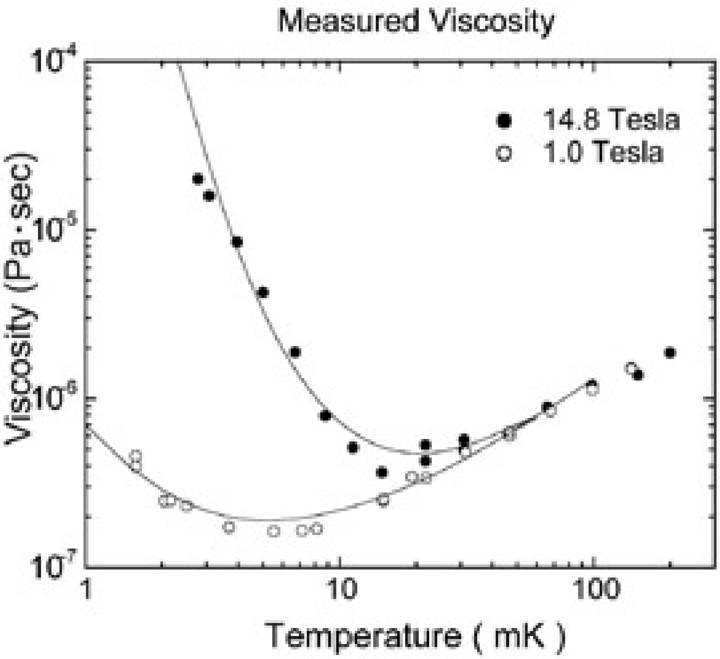

Figure 2. Temperature dependence of the viscosity of a dilute Fermi fluid, a solution of ^{3}He (150 ppm) in ^{4}He, for two different applied magnetic fields.[3]

events. The characteristic temperature at which the anisotropy sets in is given by $T_\alpha = \hbar\gamma B_0/2\pi k_B$ where B_0 is the applied magnetic field, and γ is the gyromagnetic ratio for the spin bearing species. T_α=2 mK for ^{3}He in an applied field B_0 = 15 T. For diffusion parallel to the applied magnetic field,

$$D_{//} = D_0(1+\alpha P)$$

where α is a constant of order unity. Experiments have been carried out to test the existence of this field-induced anisotropy for a solution of helium three in helium four with a helium three concentration of 3.8%.[2] For this special value of the concentration, the spin-wave diffusion coefficient vanishes, permitting a direct measurement of the diffusion without large corrections due to the Leggett-Rice effect. The measurements were carried out using pulsed NMR techniques for Larmor frequencies up to 650 MHz. The results shown in Figure 1 clearly demonstrate the existence of a strong anisotropy and the expected temperature dependence for the diffusion constant.

We have also measured the field dependence of the mean viscosity, the root mean square geometrical average of the diffusion perpendicular and parallel to the applied field, for a very dilute Fermi system, namely 150 ppm of helium three in helium four. For this dilution, the Fermi factors are very close to unity, and the system is expected to be treated reliably using first principles. The observed temperature dependences for two different applied fields are shown in Figure 2. The measurements were made using vibrating wire magnetometers[4] calibrated against helium three melting curve thermometers. For the highest field of 14.8 T the helium-three spin polarization reaches 99% for the lowest temperatures studied. The solid lines in Figure 2 are best fits to the theory, and while the fit to the temperature dependence at low temperatures is reasonably good, the absolute magnitude of the fit at high temperatures shows that some problems remain with the theory.

These experiments illustrate the wide range of capabilities available for users at the High B/T Facility; including pulsed NMR techniques up to 1 GHz, vibrating wire viscometers, melting curve thermometry and high cooling capability for signal averaging for extended time periods. The facility is available to all qualified users, and scientists interested in conducting experiments at the High B/T unit should contact either Jian-sheng Xia (352-392-8871) or Dwight Adams (352-392-0485).

1. J.W. Jeon and W.J. Mullin, *Phys. Rev. Lett.*, **62**, 2691 (1989).
2. H. Akimoto, *et al.*, *J. Low Temp. Phys.*, **126**, 109 (2002).
3. H. Akimoto, *et al.*, *Physical Phenomena in High Magnetic Field IV*, World Scientific, G. Boebinger *et al.* (Eds), P. 215, 2002.
4. H. Akimoto, *et al.*, *Phys. Rev. Lett.*, **90**, 105301 (2003).